Development of Management Information Systems in the Japanese Steel Industry

Yoshisuke INOUE

ABSTRACT: The process of information system development in the Japanese Steel Industry is analyzed from the viewpoint of management needs, technology, Human resources and green fleld of new steel works where new systems were developed.

KEYWORDS: System development, information systems, Japanese Steel Industry, production managemnt system, order entry system,

TABLE OF CONTENTS

Preface

Being a fundamental industry, the steel industry played a substantial role in the Japanese economy throughout Japan's postwar period of rehabilitation and growth. The 1950s can be seen as the era of transferring various equipment, operation and management techniques from the United States and Europe. It was also the period of digesting them.

Regarding computer technologies in general, much has been learned from the United States until now. However, as far as computer applications for the steel industry are concerned, Japanese companies could learn from the States until the first half of 1960s. It included such applications as pay roll, accounting, order entry, and process computer control. And during that time span, a fair number of system engineers and programmers were trained.

After 1965, the steel industry rushed to construct large scale new integrated steel works one after another. In this period, the so-called third generation computers, the IBM 360 and compatible domestic ones, were announced. In 1967, the Top Management MIS (Management Information System) Study Mission was sent to the United States, and the so-called "MIS boom" began. During the boom, the world's first on-line system in the steel industry was designed and implemented successfully at the Kimitsu Works of Yawata. At that time, few other on-line applications could be observed in other domestic industries.

Encouraged by the initial success of Kimitsu, steel companies worked to develop on-line production management and control systems at their newly constructed steel works, and these systems became the foundations for their own MIS.

To cope with rapid changes and progress in the management environment as well as steel making technology, effort to develop management information systems continued ceaselessly in such areas as integration and restructuring of systems at the works level as well as in sales, production management, and accounting at the head office level.

After the first oil crisis, information system departments were preoccupied with the counter-measures involved in shifting management strategy from quantity to quality and to emphasizing energy saving and the technology of continuation production processes.

Thus, by the end of the 1970s, a fair part of MIS had been developed, with the achievement of the steel industry in information systems widely regarded as surpassing other domestic industries as well as the foreign steel industry. Technical cooperation with Europe and later with the United States began in the field of production management and control systems, through which the author perceived some features of systems and the uniqueness of the environment surrounding information system development in the Japanese steel industry. This situation is clearly described for example by Luc Kiers and Bela Gold [1 : p. 73–75] [2].

In 1980s, the activities of information system were centered on the enhancement of management support systems and on the forming of network systems including trading companies. At the same time, steel companies intended to separate their information system divisions as subsidiary companies, in compliance with their diversification policies. The main objectives of the separation were to survive as the leading system integrators they had been by diversifying their potential capabilities through applications to other industries than steel, in which they had accumulated their vast experience.

This paper seeks to analyze and clarify the process of information system development in the Japanese steel industry, pointing out uniqueness of developmental environment as well as the systems features. For this purpose, the development process is divided into five eras. The experiences of the fourth era, which corresponds to the period of 1965 to 1972, is studied in particular detail because this was the period when the unique features originated. For each era, the study focuses on the management needs, the available technologies, the availability of personnel and the construction of new steel mills as well as works in which information systems were to be developed.

This paper is based on a chapter of a book written in Japanese [3] with revisions, expecting that this would become the first part of an extended study which will cover the corresponding process of systems development in the steel industry of other countries.

1. POSTWAR REHABILITATION PERIOD (1945-50)

1.1 Environment of the Steel Industry.

Because of the heavy damage from the war, crude steel production in 1946 was only 677,000 tons. The Strike Report in 1948, which announced the rehabilitation policy of the Japanese steel industry, was significant in that it decreased the worry that all facilities beyond 1.5 million tons of steel capacity would be removed as reparations [4 : p. 32] [5 : p. 29]. The so called "inclined production plan for coal and steel" was initiated in 1947, and imports of raw materials supported increasing blast furnace operations. The policy of reducing the government subsidy to the industry, which was offered by Joseph Dodge, (known as the Dodge Line Plan) encouraged such rationalization efforts as increasing productivity and saving raw material [4: p. 41].

In 1949, besides N. K. K. in the Kanto area, three companies in the Kansai area, (Kawatetsu, Kobe and Fuso (renamed as Sumikin)) were permitted to restart as integrated steel companies [5: p. 33]. In 1950, the semi-nationalized Nittetsu was forced by the Occupation Administration to be separated into two private companies, Yawata and Fuji, thereby forming the big 6 integrated steel companies.

1.2 Developments Related to Information Systems

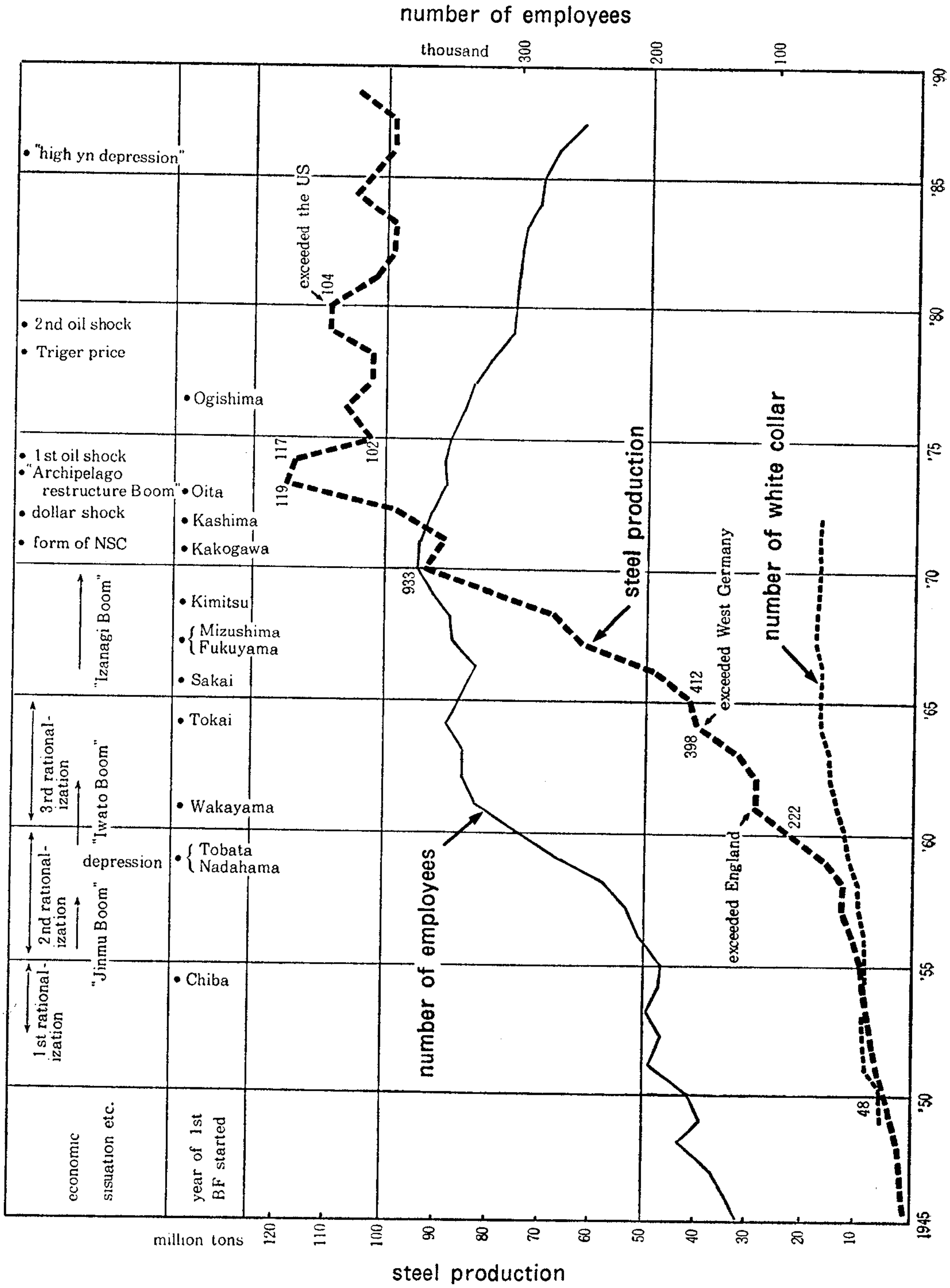
In 1950, the Steel Productivity Mission was sent to the United States to study the management of the US steel industry. The effects of the visit were reflected in the various sectors of the steel industries in Japan, including sales, accounting controls, production techniques, purchasing, labor problems and education and training activities.

Even though the information systems activities had not yet started, fundamental techniques such as Industrial Engineering, instrumentation and process controls were introduced for the first time [4: p. 79].

2. SELF DEPENDENCE OF THE STEEL INDUSTRY (1951–60)

——The First and Second Rationalization Programs——

Fig.1 Postwar Steel Production and Related Events



2.1 The First Rationalization Program (1951-55)

Influenced by the world-wide expansion of steel demand, caused by the outbreak of the Korean war, the first rationalization plan, covering three years, was prepared. The main objective of the plan was to replace rolling mills which had been devastated or had deteriorated during the war, but Kawatetsu and other Kansai companies aimed to construct integrated steel works. However, full realization of this plan was delayed until 1955 [4: p. 60]. (Refer the full company names to the list of abbreviations).

The effect of the plan was impressive. For example, steel products by 1952 costs had been reduced by 30%; the ratio of modernized equipment to total equipment had risen up to 50% by 1955 in respect to open hearth, sheet, hoop and pipe equipment, and up to 40% in heavy plate mills. Various new technologies were absorbed from foreign countries, and substantial modernization of equipment, mainly in rolling mills, was carried out. As a result, productivity was increased significantly. From 1950 to 1955, steel production doubled from 4.84 million tons per year to 9.79 million, and the coke ratio decreased from 902 to 714, the world's best record [4: p. 74] [5: p. 441].

It is worth adding that the total number of employees in the steel industry increased only slightly, from 164,000 in 1950 to 184,000 in 1960, as compared with the doubled production [5: p. 1005].

Fig. 1 shows chronological trends of steel production and number of employees.

2.2 The Second Rationalization Project. (1956-60)

Management's objective in general was to increase steel production with the available facilities and human resources (especially white-collar workers).

Initiating the so-called "Jimmu Boom", the second rationalization plan reflected the stimulated investment mood of steel companies through decisions to construct the newly located Tobata, Mizue and Nadahama works, and also to expand the existing Wakayama, Chiba, Hirohata and Muroran Works. The total amount of investment related to the plan reached ¥644 billion, about 10% of which ($300 million) was procured from foreign capital, through guarantees by the Development Bank of Japan and the World Bank. The main objective of the project was to expand production capacity. As a result, 10 blast furnaces, 15 LD converters, 6 primary mills, 5 hot strip mills, 2 cold strip tandem mills, 2 cold strip reverse mills, 2 heavy plate mills, and 7 wire rod mills were built [4: p. 91].

Technologically, various kinds of improved equipment—— including as LD converters, continuous casting, strip mills and thickness gauge controls —— were introduced from the United States and Europe. Not only equipment, but also modern American management concepts, such as the foreman system and related operational know-how, were also widely studied, modified and introduced, thus helping to provide the foundations of later information system activities. With the completion of this project, steel production had increased from 11.11 million tons in 1956 to 22.1 million tons in 1960. As a result, by 1962 Japanese steel production exceeded that of Britain, ranking Japan as the fourth steel producing country in the world [8 : p. 7].

The total number of employees in the steel industry in 1956 was around 201,000 (of which 31,000 were white-collar) in 1956, and in 1960, 300,000 (of whom 48,000 were white-collar), which means an increase of about 30% [5 : p. 1005]. As for the employment of workers, taking as an example the Yawata Works, (from which more than 3,000 employees were transferred to the newly constructed Kimitsu Works later) about 3,000 high school graduates under 25 years old were hired from 1955 to 1957. After 1958, the hiring of workers was more strictly limited to high school graduates under 21 of age. Thus, in the Yawata Works, nearly 12,000 young highly educated workers were hired from 1958 to 1962 [14 : p. 454]. As for White collars, the Yawata Works hired about 3,200 salaried employees and engineers newly graduated from high schools and universities between 1955 to 1965. It is worth emphasizing that it was those young and highly educated engineers as well as workers who were transferred to Kimitsu Works and played an important role in designing and operating on-line computerized and automated mills in the newly built steel works during the latter half of 1960s, as will be discussed later.

2.3 Development of Information Systems in the Steel Industry (1951-60)

The PCS (Punched Card System) was invented in the United States by Herman Hollerith, and was used for the Census of the United States in 1890. In Japan, it was installed in the Government

Census Bureau in 1923, and later, in Nihon Toki, Tokyo Electricity Company and several insurance companies [26: p. 23]. After the war, Yoshizawa Kaikeiki Co. Ltd. (dealer in Powers Machines) entered the business in 1947, and Nihon International Business Machine Co. Ltd. started its operation in 1949.

After 1950, Japanese top management teams began to visit the United States to study management, where there were more than 10,000 IBM PCS users. These teams realized the importance of using PCS and began to install them. Stimulated by import tax deductions in 1953, the number of installation sites increased rapidly: 116 in 1952, 220 in 1955, 303 in 1962. However, after 1960, such systems were gradually replaced by computers [22: p. 97].

In the Japanese steel industry, the first installation of PCS was in 1952, which was quite late compared with prewar installation in other business fields, such as insurance, utilities, and pharmaceuticals. In accordance with the progress of the First Rationalization Program, steel production was doubled within 5 years to 9.41 million tons in 1955. The main aim of using the PCS was to increase the productivity of white-collar employees to cope with the rapid increase of production and other new higher level management activities. Each company organized committees as well as supporting organization to promote the office-work rationalization program, although there were, of course, some differences in target area priorities.

In the case of the Yawata Works, the PCS was installed in 1952 and as its first application, the responsible section undertook to handle the payroll of 30,000 employees. The Office Work Rationalization Policy was announced in 1954, and the use of PCS was gradually extended to such areas as daily transaction processing jobs in production, the preparation of management data, and applications to technical calculations [14: p. 362].

In the case of Fuji, the Committee for Office-work Rationalization was organized in 1953 and a PCS section was initiated in 1954 for the purpose of integrating production, purchasing, sales, and accounting jobs [10: p. 582].

Both Sumikin and N. K. K. installed PCS in 1952 [19: p. 141]. Kawatetsu issued the Office Work Rationalization Policy in 1954 and then intensified the activity by establishing project teams [17: p. 488].

From 1952 to 1960, Japanese steel companies introduced such PCS applications learned from the United States as payroll, accounting, and other office-work as well as technical calculations. It was also during this period that steel companies gradually attained their rationalization aims, gaining application know-how, and starting to prepare various standards and code systems which were indispensable fundamentals for the computerization that followed. The Information Systems Forum of the Six Steel Companies, organized in 1953, has contributed much to the exchange of ideas and experience among the member companies [18: p. 626].

A strong management desire to increase production with a lesser increase in office workers can be perceived from the fact noted earlier, that steel production was doubled during 1956–60 whereas the number of white collar employees increased by only 30%. In my opinion, this strong management emphasis on production made the application targets of Japanese steel companies different from those of the American companies, from which Japanese companies had learned a lot.

For example, at the Yawata Works, centralized office work covering the production of slabbing mills and heavy plate mills was achieved in 1959, and control of each plate for each role change was made possible with the use of PCS. Also in that same year, daily, 10-day, and monthly slab yard and ingot yard material reports began to be prepared by PCS [14 : p. 368].

New and advanced management concept and systems from US steel companies were introduced by each company. At the Yawata Works, a Control Bureau was organized in 1951 to integrate such fundamental functions in production activities as production management and control, Industrial Engineering, quality control, cost control, and office work rationalization. A standard cost system was implemented and various necessary standards such as yield, tons per hour and unit consumption of various inputs were prepared [13 : p. 463]. The same kind of standardization activities were carried out at Sumikin [19 : p. 137] and other companies.

Newly rationalized management organizations and systems, in which production control was regarded as a key function, were designed and installed at the newly built Tobata Works of Yawata. Here, line and staff organization as well as the foreman system were introduced with modification, for the first time in the Japanese steel industry. Also, a newly designed centralized production management and control system began operations in which all actual production data, taken by high school graduate recorders located at each pulpit in all three shift, were sent by vacuum data transmission tubes to the centralized production control office. At the centralized office, necessary data were gathered and processed by PCS, and production activities were controlled [13: p. 463]. This new organization and system satisfied to some extent management's need for increased production and, as a valuable model of organization and systems, presented strong motivation for construction of the world's first on-line controlled steel works at Kimitsu.

3. EXPANSION OF THE STEEL INDUSTRY (1961–65) ——The Third Rationalization Program——

3.1 Further Development of the Steel Industry and Management Needs

Based upon the so-called "Double-Income Plan" of the Ikeda Cabinet announced in 1960, the Third Rationalization Plan targeted steel production at 38 million tons in 1965 and 48 million tons in 1970. According to the Second Rationalization Plan, construction of the Wakayama, Tokai (later changed in name to Nagoya), and Sakai Works was already progressing scheduled to be completed by 1965. Besides these works, The third Rationalization Plan provided for new sites facing the seashore to be used for the construction of the Kimitsu, Oita, Mizushima, Kashima and Kakogawa Works. Thus, arrangements for the planned new era of 100 million tons of steel production were ready. As for production volume, because of the so-called "Iwato Boom" in 1959 and 1960, maximum production to the capacity was required. However, regardless of the increased steel production due to the export increase, in 1962 and 1965, the domestic demands were decreased, and the steel industry faced the most difficult time since the war ended, and reductions in production as well as in costs were required. Thus, the market environment became more severely competitive. Despite the depressed domestic market situation in these years, the amount of steel exported increased from 2.22 million tons in 1960 to 4.12 million tons in 1965. As a result, Japanese steel production exceeded that of West Germany in 1964 and was ranked third in the world [6 : p. 58-62] [8 : p. 9].

The total number of employees in the steel industry was around 335,000 (of whom 54,000 were white collar) in 1961, and rose only to 343,000 in 1965 (of whom 63,000 were white collar), compared with a doubling of steel production. White collar employees, increased by about 6,000 between 1961 and 1962 [6: p. 543].

3.2 Need for and Development of the Information Systems in the Steel Industry

In 1960, the IBM 7070, the largest second generation computer, was announced in Japan. In 1961, N. K. K. and Yawata each installed one. The rental fee for the machine was about 13 million yen per month in the case of Yawata [14 : p. 371], and the total expenditure per year was 260 million yen in the case of N. K. K. [16 : p. 247]. Considering that the average monthly income of steel industry employees at the time was about 40,000 yen [6 : p. 543], the computer fees corresponded to the pay of more than 300 employees. It can be said that this was a significant decision by top management, because it had the merit not only of higher office work productivity in the existing steel works, but also provided an opportunity to acquire knowledge and experience in using computers for those who subsequently contributed to the development of systems in newly constructed steel works.

In 1961, Kawatetsu and Kobe installed their first USSC-80 computers, and Sumikin installed a NEAC-2203. In 1962, Fuji installed a NCR-304 at its head office. Thus, each company had finished installation of second generation computers by 1962. It should be noticed that each company tried to develop batch-type data-processing applications in steel works, especially production-related office work, in order to comply with the management requests for production increases [17: p. 490] [18: p. 626] [10: p. 586–595].

As the first stage of application, computers were used mainly to gather actual production results and to prepare work instructions for mill and plant operators. At the Yawata works, a computerized system for monthly and quarterly production planning was developed in 1961 resulting in shortening the past preparation period from one week to one day [24]. Subsequently, the standard cost and profit estimation systems started operation in 1962, and the monthly actual cost reporting system by products was started in 1964 [9: p. 560]. Through these activities, various standards such as tons per hour, yields, and unit consumption were gradually prepared, and system personnel were trained.

These applications responded to management's need not only to increase production to maximum capacity during the Iwato Boom period, but also to decrease production costs during the domestically depressed period in 1962 and 1965 [8: p. 10]. Experience in developing and operating batch-type systems using the second generation computers also accumulated among young engineers at moderate-size steel works which had been constructed before

1960. This experience, combined with process computer and communication technologies learned from the United States in the 1960s, provided the foundations and encouragement for developing on-line systems at the new giant-size steel works constructed after 1965. Thus, the accumulated experience and technologies were transferred from N. K. K.'s Keihin Works to its Fukuyama Works, from Chiba to Mizushima (Kawatetsu), from Yawata and Tobata to Kimitsu (in the case of Yawata), from Nadahama to Kakogawa (Kobe), from Wakayama to Kashima (Sumikin), and from all NSC works to Oita (NSC).

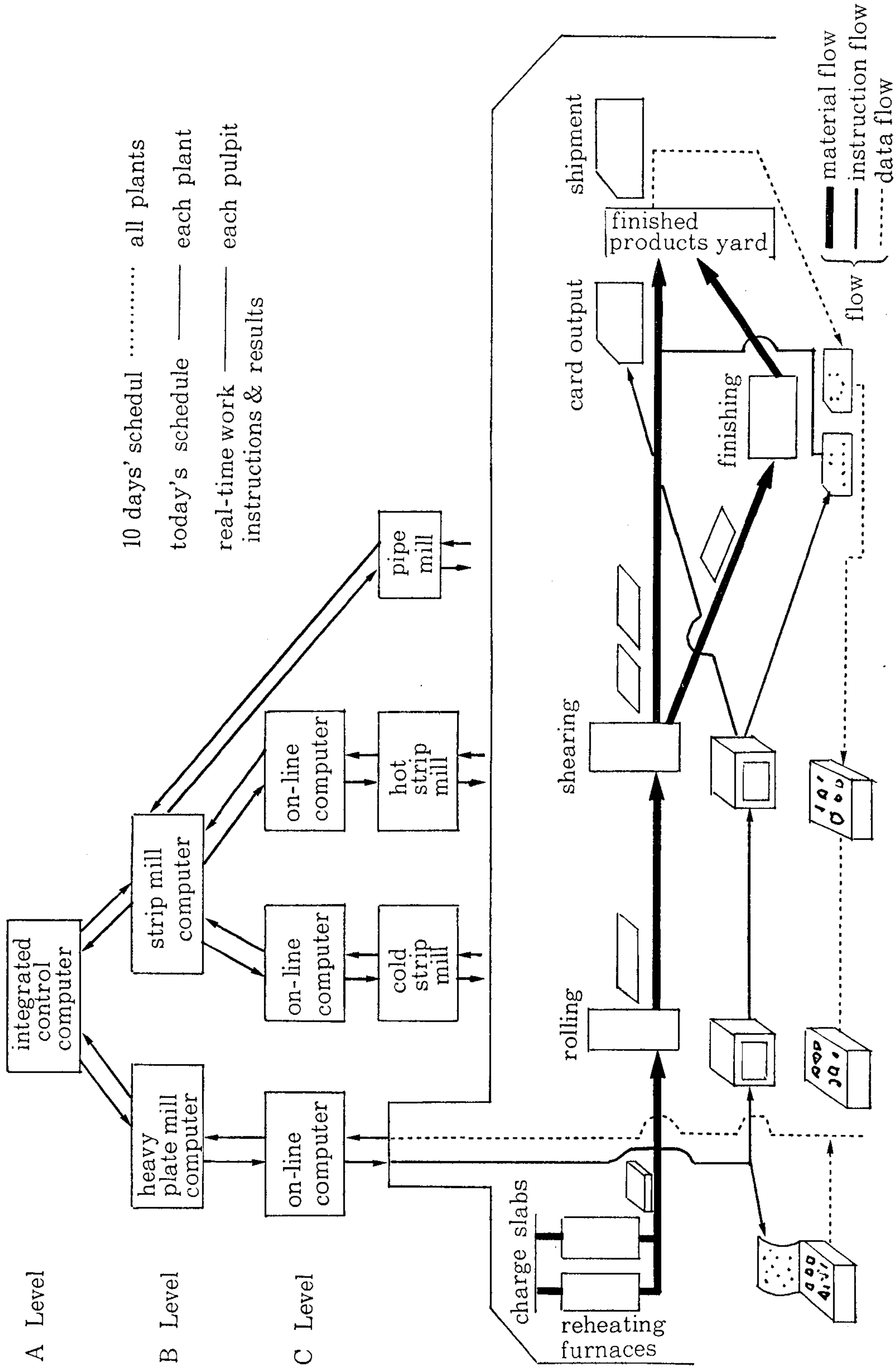
In the case of Fukuyama and Mizushima, partly because they were designed prior to the announcement of the third generation computers, computer applications started with data gathering and work instruction transfer through process computers. However, in the case of Kimitsu Works, when the general design of the production management and control systems started in late 1966, the third generation computers had already been announced and some data and experience in their on-line applications, such as the Systems for the Tokyo Olympic Games, were available. Benefiting from many other fortunate conditions, the Kimitsu Works was successful in developing and operating the world's first works-wide on-line production management and control systems (known as the ALO, or All On-Line System) in 1968.

4. ARRIVAL OF THE AGE OF 100 MILLION TONS STEEL PROODUCTION (1966–72)

4.1 Environment of the Steel Industry

In accordance with The Third Rationalization Plan, within less

Fig. 2 Concepts of Production Control at Kimitsu Works (as of 1968)



Hiearchy of System Control Level

Cotrol Level	Span of Control	Control Cycle	Control Objectives	Main Job Content
A	whole Works	daily for 10 days	planning, processing data	order acceptance, order modification, material request, progress status, production & shipment records
B	plant	by day, by shift	scheduling by day by snift based on processing date & actual results	data gathering (by day by shift). prepare instructions for shift, decide quality
C	main equipment	by shift by few seconds	deliver instructions & data gathering	deliver instructions disply, inquiry, repoting
D	each pulpit in plant	within few seconds	give work instructions & control	optimization, automatic control

than ten years, the construction of gigantic new steel works and the start-up of their first huge blast furnaces took place consecutively : Tokai in 1964 ; Sakai in 1965 ; Fukuyama in 1966 ; Mizushima in 1967 ; Kimitsu in 1968 ; Kakogawa in 1970 ; Kashima in 1971 ; and Oita in 1972. Consequently, steel production increased rapidly from 41.1 million tons in 1965 to 119.32 million tons in 1973. All of these gigantic new steel works were started operations with the full support of the already existing, comparatively new, steel works of each company. All of them developed the same kind of hierarchically structured on-line production control systems, as shown in Fig. 2 (taken from [30: p. 136, p. 138]), which were regarded at the time as high level achievements [1: p. 73] [2].

Mass transfer of workers took place in each company, supported by good management and labor union relations. For example, the Mizushima Works of Kawatetsu was supported by its Chiba Works. The Kashima Works of Sumikin was constructed with the slogan "Let's start Kashima with a company-wide effort", and 2,675 workers were reported to be transferred from Wakayama between 1964 and 1966, and about 1,700 workers were transferred to the Fukuyama Works from the Keihin Works which is nearly 800 km away, and 2,200 more were also transferred among 3,000 who were added for the operation of its second phase of construction [7: p. 70].

In the early part of this period, the Japanese economy enjoyed the so-called "Izanagi Boom" from 1965 to 1970, GNP increased 11.6% per year, and annual increases in mining and industry production averaging 11.5%, two or three times greater than corresponding figures for the US or Europe [7: p. 21-22]. Also, in 1970, Yawata and Fuji merged to form Nippon Steel Corporation (NSC), which became the largest steel company in the world, replacing U. S. Steel in the position.

During the latter half of 1970, a depression started. In addition to the poor domestic demand, the so-called "dollar shock" in 1971 forced a rationalization effort on companies to increase the ratio of LD to Open Hearth steel production as well as the ratio of continuous casting versus ingot making [33: p. 13]. Also, because of the rapid economic growth, anti-pollution problems became serious issues in the latter part of the 1960s. Anti-pollution investment in the steel industry reached 209 billion Yen in 1975, equivalent to 18% of its total investment of the year [4: p. 207].

Economic circumstances turned more favorable in late 1972, which stimulated an increase in steel production to 119 million tons in 1973, nearly equal to the steel production of ECSC, as well as of the US and USSR. However, because of the "oil-shock" in the Fall of that year, the economy again turned into a depression phase.

Because of Japan's rapid economic growth, demand for steel kept increasing, but the opening of numerous gigantic new integrated steel works also increased supply, which led to keen sales competition in a buyer's market.

Strong demand for labor from the tertiary industrial sector caused a serious shortage of labor after 1963 and 1964, and young labor power became especially serious during the period of rapid economic growth from 1968 to 1973. However, it is surprising to find how slightly the total number of employees in the steel industry varied: rising from about 343,000 in 1965 to a peak of 379,000 in 1970 and decreasing only to 356,000 in 1973 [6: p. 548]. Despite the fact that during that same period seven gigantic new steel works started operation, and steel production nearly tripled.

This astonishing achievement resulted from well prepared plans of each steel company which consisted of various efforts such as to transfer a large numbers of young but experienced people from existing steel works to newly constructed ones as we have seen above, and developing information systems as will be explained in the following section.

4.2 Development of On-line Production Control System

——Taking the Kimitsu Works as an example——

Taking kimitsu as an example among those seven newly constructed steel works, a detailed analysis can now be presented to clarify why the Japanese steel industry was successful in the early development of higher level of on-line computerized systems, while enterprises in most other domestic industries as well as in other foreign steel companies were not as yet. The reasons why Kimitsu system is selected as the target of analysis are first that it was the world's first example, at least in the steel industry, of implementation of on-line systems running 24 hours a day; second, that I myself participated in designing the system; and, third, that references are comparatively abundant.

(1) Management need for information system

When the Kimitsu Works started construction in 1965, the following policy was established: "Let us construct our works with ideal facilities and equipment based on predicting tomorrow's technical trends, and establish the management system best suited to operate them." Because the Kimitsu Works started operation in 1968, in the midst of the so-called "Izanagi boom", which continued into the first half of 1970s, Kimitsu was urged, from the very beginning of its operation, to increase production as quickly as possible to the maximum capacity. As mentioned previously, there were two other obvious management needs: one was to save manpower to cope with the imbalance of labor demand and supply; the other was to deal with competitive cost, quality, and delivery terms, or more precisely, to comply with the customers' requested dates, in spite of smaller lots as well as frequent changes of orders caused by the severe market environment [9: p. 569].

(2) Promoting Organization of Information System

The construction of the new Kimitsu Works, which was expected to be equipped not only with the newest equipment and technology but also with the most competent management system, was pursued as a company-wide project, with the slogan "promote the Kimitsu project by our own hands" [14: p. 455]. The Yawata Works, which is located more than 1,000 km west of the Kimitsu Works, played the role of the mother works.

In January of 1967, the Kimitsu Project Bureau was organized at the head office of Yawata. The Bureau was responsible for establishing management policies for the design and operation of the new works, while the Construction Bureau, which had already existed for many years, was responsible for the actual design and project management of plant facilities and the relevant software in accordance with established policies.

The management policies were clarified by the Bureau as follows: (i) development of an organizational structure and system which would realize to the maximum extent the benefit of the consumer-oriented works location; (ii) unprecedented pursuit of manpower efficiency; and (iii) maximum employment of computers.

These policies, combined with the accumulated experience of management and technology, which is described below, resulted in the following innovative design philosophy of the Works: "In the new steel works, plants and equipment as well as their lay-out and operational methods should be designed on the basis of the state of the art in automation, process control and on-line control technology of the time" [9: p. 569-570].

In accordance with this policy and the design philosophy, the batch control system group, the on-line control system group, and the process computer control system group——all of which were organized in the Construction Bureau——worked together to carry out the integrated production management and control system parallel with the design and construction of the plants, which were carried out by each plant design group in the same Bureau [15: p. 525].

Members of these systems groups in the Construction Bureau were selected from the various existing functional organization sections. The percentages of selected members from each section to the total number of personnel were as follows: process computer section 35%, business computer section 27%, production control section 18%, quality control section 9%, instrumentation section 4% and other sections 3%. They were a mixture of engineers and clerks [9: p. 575], and one of the important reasons why the system project was carried out smoothly and successfully was that they taught their specialized functional activities to each other so as to integrate them as a system.

From the Yawata Works only, total number of 580 of highly graded engineers and clerks (including system designers, programmers and computer operators etc.,) were transferred to the Kimitsu Works in the latter half of the 1960's. About 80 from the business computer section, more than 100 from the production, IE and process computer sections. From 1964 to 1969 only, also more than 2,600 workers, some of whom became operators of the mills (who operated computer terminals as well), were transferred to Kimitsu [14 : p. 455, p. 278]. I believe, it was one of the important factors in the project's success that this large number of white-collar as well as blue-collar employees, who had had enough experience to understand the actual jobs but not so much as to become reluctant to change from conventional to innovative methods. These became the key persons in designing and implementing the new system as well as in operating production equipment and computer terminals in pulpits.

(3) Challenge to Innovative Technology Based on the Transferred Accumulated Technology in Conventional Works

In addition to the transfer of personnel, various accumulated technologies and individual systems in Yawata and other works were also transferred to the Kimitsu Works, where they were integrated and structured into innovative new systems.

Computer utilization technology.

Utilizing an IBM 7070 computer installed in 1961 at the Yawata Works, computerization of quarterly and monthly production planning, as well as of actual production data gathering were realized, parallel with the development of applications of planned cost and profit forecasts, along with actual cost calculations [14 : p. 372] [24]. As a result, comparatively high level batch-type data processing technology accumulated in the area of computerized production management and control application, even though on-line applications were limited to the restricted area of process computer control.

Process computer and instrumentation technology.

In the Yawata Works, an instrumentation sub-section was organized in 1945, which in 1955 became the section in charge of instrumentation as well as automatic control. Towards the middle of the 1950s, several papers on computer control in steel were written [34]. In the Tobata area of the Yawata Works, mathematical models for computer control of LD converters and hot strip mills had been studied since 1964 based on technical transfer from the US, and actual operations were started in 1964. The experience and results of these process computer control developments as well as related communication technologies contributed much to the widespread use not only of process computers, but also of on-line application to business-use computers at the Kimitsu Works [14 : p. 168] [57]. As I recall, the issue whether business-use computers (namely the IBM 360) or process control computers should be adopted for the on-line production control systems was seriously discussed. However, the latter were regarded as less reliable than the former at the time. As a result, a kind of dual system was adopted, in which production orders as well as actual data were transmitted and processed by the former, while the process control of furnaces and rolling mills was under the responsibility of the latter, except in the slabbing mills where the process control computers filled both functions. At the Oita Works, which started operations in 1973, the design philosophy was changed to use the local process control computers for both production and control functions, whereas the centrally located business-use computers were responsible for managing operations of integrated mills. This change occurred mainly because of the increased reliability and memory capacity of the process control computers to facilitate distributed controls [10 : p. 610].

Organizational structure, production management and control

As described earlier, in the Tobata area of the Yawata Works, a batch-based monthly, daily and shift production management and control system covering operations from the LD converter area to the cold strip mills was functioning rather successfully even though there were several difficulties to be overcome [30 : p. 133]. The system was designed to incorporate the line and staff system concept (with centralized production staff, threeshift dispatched data-men who transmitted work instructions as well as actual data, punch operators, and batch-based data processing computers and operators). Studies seeking to change this batch-based system into an on-line system were started in 1965. Even though these studies were not realized in Tobata because of computer hardware difficulties, as well as resistance to change from a conventional system to a new system, the outcome of the study contributed much to the realization of the on-line system in the Kimitsu Works.

As for the heavy plate, batch-based production system in the Yawata area, which enabled each plate to be traced through previous processes (such as blooming and open hearth) by using accompanying-cards sent through a vacuum tube, this was operating successfully. In 1967, the HITAC-9930 data transmission system was introduced to support 120, 000 tons per month production at the heavy plate mill [9 : p. 571].

Industrial Engineering and related technology

In the early 1950s, various new management methodologies were introduced from the US. In the report of the Steel Productivity Mission sent to the US in 1955, the importance of the Industrial Engineering (IE) function in efficient management was stressed. This report triggered a systematic study of IE in the Japanese steel industry. The IE Study Conference for Eight Steel Companies was organized, and an IE section was organized at the Yawata Works in 1957. Typical activities of IE in those days involved were the promotion of standardization: preparation of standard operations; setting time standards for production capacity estimation; and so forth. Plant studies to promote production efficiency were a common practice, utilizing operation research techniques. The IE section in Yawata was enlarged into an IE department in 1961, which contributed to decisions on the required number of workers and sub-contractors at each plant, in compliance with management's instructions to cope with the depression of 1962. They employed OR techniques such as simulation to design improved plant operation systems [14 : p. 33–39].

New information system-related technology: Challenge to on-line system

Through accumulated experience, the following facts were confirmed in the Yawata Works: (a) as long as conventional systems consisting of three-shift production-data handling workers, vacuum tube data transfer facilities, key punch operators and batch-based data processing were being used, an improved management level could not be attained due to the two or three days' delay in preparing production reports; (b) when adopting conventional systems, a fair amount of data processing as well as data handling personnel were indispensable; (c) it was difficult to change from an already operating conventional system to a new computerized system due to the reluctance of operating staff.

Because of these facts, the following concept was generally agreed on: the new on-line production system at the Kimitsu Works should be designed simultaneously with the design of plant layout, plant operation, and plant staffing, so that the system could start functioning from the very beginning of production [30 : p. 133] [28].

Adoption of the new on-line production control system was also necessitated by the difficulty of hiring workers due to imbalance of labor demand and supply. With the support of the system, the mill operator himself could receive work instructions from terminal displays in front of him and could send most of the actual operational data sent back automatically to computers, based on the concept of control by exception. With this concept, if production were carried out as instructed, the content of the work instructions itself could be reported automatically as actual data; only in case actual production differed from the work instruction would the actual data had to be keyed in by the mill operator. It would be possible to reduce the number both of three-shift data-gathering workers, and of input errors while achieving high level mill operations and guaranteed attainment of a high percentage of work instructions.

On-line control of integrated steel works, however, required unprecedentedly severe computer utilization conditions involving twenty-four hours of continuous operation for every day throughout a year. This condition, different from other business fields, comes from the fact that unexpected shutting down some mills beyond a certain hours degrades the smooth operation of blast furnaces which is fundamental to the effective operation of steel works.

Fortunately, the so-called the "third generation" IBM 360 was announced in Japan in 1964, and the hardware obstacles to the design of on-line systems for continuous operations had already been removed by the time the Kimitsu System Project was started in 1966. As for on-line applications, the Tokyo Olympic Games and the Mitsui Bank began to operate their systems in 1965 with the IBM 1440, even though they did not involve operating conditions as severe as in steel works. Thus, prior to designing the Kimitsu system, Yawata's staff was able to study the planning as well as the installation of on-line systems inside and outside Japan. In steel companies in Europe and the US, only small scale experimental on-line systems were observed. Domestically, the on-line production system in the Oppama Plant of Nissan Motors was worth studying. Studies were also made also on newly constructed steel works, such as the Fukuyama Works of N. K. K and the Mizushima Works of Kawatetsu. Their interest seemed to be more in using process computers and order entry system application than in on-line production control, so that these studies did not provide useful information to the Kimitsu staff. It became clear, therefore, that Kimitsu staff itself would have to solve its difficult problems [9 : p. 572].

In particular, Kimitsu had to develop the following technologies with the support of main-frame and instrument suppliers: (a) communication technology to transmit data among remote terminals and centralized computers; (b) technology to use magnetic disks to store and process large amount of production data; (c) technology which managed both hardware and software, such as a disk operating system. Even though they still had technical difficulties to overcome, the top management decided to develop an on-line production system, supported by the strong willingness of young staff to challenge the new technology. After an intensive effort, the world's first All On Line (AOL) System —— which covered all stages from steel-making to the shipment of heavy plate, hot and cold rolled and other products —— was successfully developed within less than three years after the start of the general design in 1966.

The system covered operations from the very beginning of production in each mill as planned. The upper limit of computer hardware investment cost was set with regard to the amount of man-power cost saving to be gained by adopting the system, and was kept well under that limit. Thus, the merits both of cost saving and of improved management could be achieved. The required man-power to develop the system was about 200 man-years [30 : p. 134], and an estimated saving 2,200 to 2,300 workers at plants was achieved by use of the system [48 : p. 17]. The general concept and rather detailed explanation of the Production Management and Control System at the Kimitsu Works (the AOL) are available in the cited references [27][28][58], and in the schematic in Fig. 2.

(4) Key Factors of the Success in Kimitsu's On-Line Pfoduction Management and Control System

Key factors in the success of AOL can be summarized as follows [9 : p. 573] : (a) top management's positive decision-making based on reliance on employees' willingness and capabilities ; (b) effective use of various accumulated technologies in already operating works ; (c) company-wide cooperation with the Kimitsu Project Bureau which designed and implemented the new management policy and philosophy ; (d) integration of all the related design and implementation functions, such as mills and facilities, production procedures, production management and control, IE, computer systems, control and instrumentation, within the Construction Bureau ; (e) participation in the system design phase of mill operators who were also expected to use on-line terminals ; (f) transfer of abundant well-trained employees as well as technologies from Yawata and other existing works under the companywide slogan of "promote the Kimitsu Project by our own hands"; (g) the innovative and dedicated effort of all the participants ; and (h) the higher level of production performance as well as employees' willingness to carry out scheduled instructions to realize them as actual results, which was part of the fundamental philosophy of the system : the concept of management by exception.

So far, only the case of Kimitsu has been described here. However, although the timing of system developments was diversified in later periods, the system development promotion methods of other Japanese companies were similar to those of Kimitsu. The five years after 1966 correspond roughly to the period when most of the computer control systems of the Japanese steel industry achieved remarkable progress compared with those of Europe and the US.

According to my experience with technical cooperation in respect to the production management systems of steel companies in Europe and the US, the factors unique to Japanese steel companies, which seems most to facilitate the successful systems developments, were the above-mentioned (d), (e), (f) and (h). In a word, the uniqueness of the Japanese system development methodology could be described as well-organized teamwork of a fair number of qualified interdisciplinary members aiming at one common goal. Prior to writing this paper, I visited several steel companies in Japan, and found that the belief was shared among those who had the same kind of technical cooperation experience.

(5) Kimitsu Second Expansion Project, System Integration, and Technical Cooperation with Other Countries

In the Kimitsu Works, the construction project and the subsequent first expansion project were completed in 1969, with the hot gas blowing in of No. 2 blast furnace and the starting-up of the related mills and plants. Next, the second expansion project was pursued which consisted of the construction of No. 3 and No. 4 blast furnaces and other related mills and plants such as second LD converter plants, second blooming mills, shape mills, and pipe mills. Individual production control systems for these plants and mills were developed and installed together with the start-up operation of corresponding plants and mills. In addition, comprehensive production management and control systems covering all the stages from blast furnaces to the shipment of products were modified or restructured, when each of component plants or mills started operation.

In parallel with these systems, quality control, budgeting, accounting, and cost control systems were also developed in Kimitsu and gradually integrated into what was named KIIS (Kimitsu Integrated Information System) [15 : p. 530–p. 535].

With the KIIS model successfully developed and operating, technical cooperation projects in the system analysis and design phase for integrated steel works were started for the first time in Brazil and Italy in 1972. Since then, technical cooperation in the system field has been gradually extended to several other steel companies in Europe and in the US by NSC and other Japanese steel companies [7 : p. 656].

4.3 Implementation of Order Entry System (O. E. S.)

As previously mentioned, with the expectation of a rapid increase of production in several newly constructed gigantic steel works, market conditions became more and more demanding on the one hand, while each company was also required to distribute its orders to several mills at different locations. In order to cope with these management requirements, each company began to study the order entry system in the US, and started to design and implement similar systems [9 : p. 582]. Activities of several companies in this area are briefly described below.

Kawatetsu formed a study team on rationalizing sales office work in 1965, to be ready for application to expected steel production practices in two big steel works in eastern and western Japan.

As outcomes of the study, it introduced a Univac-494 in its head office and a sales information system which began operations when the heavy plate mills at Mizushima (western production base) started up in 1967. After that, the products covered by the system were expanded one by one to strip, shape, coil, and bar. In 1969, an order center was opened, whose main objective was to centralize the processing of data from order acceptance and production to shipment. The center, which had a coordination function between the sales and production departments, succeeded in facilitating the activities of both departments [17 : p. 493].

Sumikin started operation of its sales information system for plate products in 1969. At the same time, computers at the head office and at each works were connected. A team to study development of an order center was organized in 1970 to investigate such items as appropriate mill balancing, shortening of delivery times, better customer service, and the fundamentals of order and production processing. In 1971, the order center started its function, and the coverage of the system was extended from plate to pipe and then to sections [20 : p. 137–p. 140].

Fuji started design of an order processing system for plate products in 1965 and installed the system next year. This system became a core part of the order entry system, development of which was initiated in 1967. Since then, the kinds of products to be covered by the system were extended gradually, and an order center was organized in 1969 [10 : p. 307, p. 603].

Kobe redeveloped its order processing system so that orders could be accepted by magnetic tapes, at the same time when partial unification of format and code for the steel industry were realized in 1973. And in 1975, the independently developed order acceptance and billing systems of each works were integrated, and the new order entry system initiated its operation under the control of the steel sales division in the head office [18 : p. 627].

Yawata recognized the important function of the "roll center" and the "order entry system" of steel companies in the US, and began to study them just after the construction policy of the Kimitsu Works was announced. The O. E. S. study team, consisting of sales, technical, and system staffs was sent to the US and Europe. Taking into consideration the study results as well as the Japanese business environment, a development policy for an order entry system was formulated. The policy planned development of a centralized system consisting of product by product sub-systems, with mill balancing function, but without a customer crediting function, which in Japan was mostly taken care of by trading companies. The roll center at the head office began operations between 1967 and 1968, depending on the products it covered. By that time, batch-based order processing and mill balancing systems had been developed and the order entry system started operation [9 : p. 582]. Owing to the merger of Yawata and Fuji to form NSC in 1970, the restructuring of a new O. E. S. for NSC required two years, and the resulting system started operations in 1972 [11 : p. 346].

Under the auspices of the Kozai Club (Iron & Steel Institute of Japan), six integrated steel companies and seven trading companies had worked together for several years, to develop a standardized code and some format applicable to order processing which was completed in 1969. This activity was highly regarded as the first case of an industry's defining a common business protocol and contributed much to the promotion of information systems in the steel industry [18 : p. 627] [49 : p. 22].

4.4 Development of Management Information System (MIS)

In the Fall of 1967, a Top Management MIS Study Mission visited the U. S. to investigate the state of the art of MIS. From the steel industry, Vice President Hirai of Yawata jointed the mission, and the author accompanied him. The resulting report was so optimistically treated by journalism that the socalled "MIS boom" arose. As a reaction to this publicity, those who observed the activity only superficially, criticized it, saying MIS was a "MIStake". However, the report of the mission proposed a long range MIS promotion plan for private enterprises including the fallowing recommendations: (1) top management itself should be responsible for the promotion of MIS; (1) in developing a long range MIS plan, the first priority should be those applications which could produce operating benefits quickly only gradually widening to broader levels of management; (3) simplification and standardization should be promoted to improve the information system environment, starting from such fundamental functional areas as production, sales, and accounting; (4) computer and system education should be conducted continuously to support the long range MIS plan; and (5) labor problems related to computer systems should be solved through agreements between management and labor unions [32 : p. 7]

Steel companies fully accepted this report, and followed the suggested guideline. They started with applications to production and order entry systems, which were needed most and offered the most productive of benefits. Then, taking more than ten years, they gradually developed wider applications to pursue the longer potentials of the MIS master plan [9 : p. 581]

Kawatetsu claimed that the business information system for heavy plate at Mizushima could be regarded as the initiation of MIS activities in the company [17 : p. 494].

In Fuji, it was noticed that the proposal of the Top Management MIS Study Mission enhanced interest in computers not only among those who participated in designing information systems but also among top management, as well as managers of system users [10 : p. 602].

In Yawata, just after the MIS Mission's report was announced, the MIS promotion group was organized in the Business Administration Department of the head office. The group, after investigating computer usage at the head office as well as each works at that time and in the near future, made a report to the top management on the corporate level's long range MIS policy which clarified priorities in system development, and in human resource planning, including education, and also cliarifed interfaces among systems. The policy was approved and put into practice [9 : p. 581–p. 582].

Each steel company continued to study and develop its own MIS in accordance with its own policy, even after the so-called "MIS boom" had calmed down. In the steel industry, the outcome of these efforts facilitated the adoption in time of fully computerized and automated production management and control systems at consecutively constructed new efficient steel works, which played a significant role in promoting rapid economic growth in Japan in the decade after 1965 [7 : p. 677-p. 678].

5. COUNTERMEASURES FOR OIL CRISIS AND QUALITATIVE CHANGE OF MANAGEMENT (1973-)

——Promotion of MIS : Restructuring of Production Management and Control Systems, O. E. S., Integration of Systems——

5.1 Environment of the Steel Indudtry

From the latter half of 1972 to 1973, there was recovery of favorable economic circumstances. It is worth recording that in 1973, Japan's GNP increased by 8.2%, and its steel production reached its all-time record of 119 million tons, close to US's 136 million tons and USSR's 131.5 million tons. However, the oil shock in the Fall of 1973 caused damage to the world economy and decreased the GNP of all the industrialized countries. The Japanese steel industry suffered serious restrictions on oil and electricity usage, and faced a difficult situation. Steel production decreased in 1974 and 1975 to scarcely more than 100 million tons, and intensive efforts had to be continued to overcome the difficulties caused by the depression.

Even though the economy turned favorable in 1976, it became worse again in 1977 and the depression seemed to continue. In the United States, the Solomon Report was published at the end of 1977. As the Trigger Price was introduced, it became necessary to pay more careful consideration to exporting steel to the United States [7 : p. 24][54].

Steel production in 1978 was 102 million tons, and the economy turned towards a favorable direction. The improvement of the steel market, accompanied by the hard rationalization efforts of each company made 1979 the most prosperous year for the steel industry since 1973.

The favorable economic situation continued until the first half of 1980. In the latter half of that year, however, the economy turned down, and production was slightly reduced to 111.4 million tons, which exceeded US steel production of 101.4 million tons. Thus, the Japanese steel industry took for the first time the second ranking in production after the USSR.

The second oil crisis, which occurred in the fall of 1978, stimulated each company to pursue further efforts to reduce energy consumption, particularly oil. Owing to the world-wide depression from 1981 to 1982, domestic and foreign steel demand decreased. As a result, production fell below the 100 million tons level in 1982 and 1983 [8 : p. 20-p. 32].

Even though domestic as well as foreign steel demand rose in 1986 and 1987, the Japanese industry faced a depression caused by the progressively very higher Yen/Dollar exchange rate, and all the Japanese steel companies accelerated efforts to diversify into such areas as engineering, new materials and information services [8 : p. 47-p. 52].

After the first oil crisis, intensive efforts were made to reduce energy consumption. As for plant and facility adjustment in this connection, in 1975 two LD converters were added to the total of 98, the number of continuous casters reached 122 with new construction of 11 casters. Parallel with such investments, there were continued efforts for energy saving through such means as increasing the number of charges of steel making per one campaign of LD converter operations and increasing the continuing operations of continuous casting [55 : p. 8]. The second oil crisis stimulated further energy saving efforts which had continued since the first oil crisis, and various measures were taken to reduce use of oil. Consequently, the use of continuous casters increased so rapidly that the ratio of slabs and blooms cast by continuous casters to total production of slabs and blooms increased from 21.1% in 1973 to 59.5% in 1980, and to 91.1% in 1985 [56 : p. 46]. As another energy saving technology in rolling mills, the Hot Direct Charge (HDR) operation was invented and practiced with an enormous amount of energy saving [8 : p. 24]. The HDR required large scale as well as very sophisticated restructuring of production management and control systems, as described later.

5.2 Need for Management Information Systeme in the Steel Industry and It's Development

During this period, there were large and rapid changes in information systems. The IBM 370 computer was announced in 1970 in Japan, and since then various new types of computers, including products of Japanese main frame manufacturers, have been developed one after another. Arvin Tofler's "The Third Wave" was published in 1980, and the concept of the information society attracted interest. In the first half of 1970, the so-called software crisis became a serious issue, and office automation (OA) spread.

Also, the prevalence of personal computers and word processors with software which allowed one to use kanji (Chinese characters) influenced the information environment significantly. In 1980, the new communication law which opened the communication industry to private enterprise became effective, and new applications were developed along with new computer networkes and businesses introduced.

In the steel industry, the management information systems of each company have been reconstructed as a rerult of intensive efforts in order to respond to the various above-mentioned management requirements. The prototype of MIS in the steel industry is shown in Fig 3 (taken from [59 : p. 25]).

The following several sections describe the major elements of restructuring which were necessary to cope with changing management requirements for the period ahead.

(1) Restructuring of Production Management and Control Systems

Since the first oil crisis in 1978, counter-measures for dealing with the increasing intensity of sales competition and of energy saving have been requested by management.

To cope with this need, innovative improvements in manufacturing processes were introduced. Typical examples included: (a) changing from the ingot making and slabbing process to the continuous casting process; (b) charging hot slabs into hot rolling mills directly from continuous caster (direct charged rolling); (c) changing from batch annealing to the continuous annealing process in cold rolling operations [8 : p. 277–p. 280].

Changes in the continuous casting process necessitated system restructuring: one example being to change the target of material requests from one charge of LD converter to several charges in favor of specifying required combinations of cast slabs. Another example of the required system restructuring was to eliminate such time and space buffers as the ingot molding process and yard, ingot rolling processes and yards for slab cooling, as well as slab reheating operations [36 : p. 11].

As a much higher level of processing technology, the direct charged rolling process was invented. This facilitated further savings of energy and other resources as well as shortening processing time from steel making to rolling, through the adoption of the continuous casting process along with a restructured and more sophisticated computer control system. In order to practice this new process successfully, planning and scheduling systems had to determine steel grades as well as the amount to be refined in LD converters, and at the same time had to determine how to cut continuously discharged slabs so that the cut slabs met the order specifications for the products of subsequent hot rolling operations. Moreover, the necessity of seeking to consider synchronize the operations of each of the continuously cascaded processes makes the system more complicated and sophisticated. In other words, coupling the operation of continuous casting and direct charged rolling requires not only synchronized through-processes control function from LD converters to rolling mills, but also integrated control functions for both production and quality. These control functions could not be achieved without integrated use of business and process computer control systems. Each company has tried to develop these highly sophisticated systems and has attained the satisfactory results [36 : p. 11].

As for the contributions of computer systems to the management of the steel industry in general, the Trigger Report gives objective figures. The report analyzed the major factors involved and their contribftion to the 12.7% (83.7-71.0=12.7%) yield differences between the Japanese and the American steel industry as follows: 3.2% from computer system difference; 6.9% from the higher ratio of continuous casting; 1.8% from other eqnipment differences; 0.8% from product-mix differences [48 : p. 17].

(2) Restructuring of Order Entry System

After the first oil crisis, the sales environment changed in favor of the enhancement and diversification of product quality. Around 1983, each company started to restructure its order entry system, parallel with the above-mentioned restructuring of production management and control systems at each works.

Including partial operation, Kawatetsu, Kobe and Sumikin started operation of new systems in 1985, and NSC in 1981. Common objectives and features of these systems were: (a) to cope with the new production practice of small lots for multiproducts, changing from the conventional practice of mass production with less products variety; (b) to increase the percentage of computer-acceptable items in order-sheets so as to shorten the time required for the order acceptance process; (c) to receive orders from trading companies through on-line communication lines instead of the previous method of magnetic tapes and hand-written comments; (d) to facilitate the mutual use of information among such functions as sales, production progress, and transportation of products, so as to provide the fundamental system functions required to become a part of higher level VAN (Value Added Network) systems in future [40].

The amount of effort extended by each company to restructure order entry systems was enormous; for example, NSC realized its first phase (covering only heavy plate and hot rolled products) required almost three years' 3,200 man-months work load in order to develop 1.8 million logical steps of programs [42] [43].

A general description of how this order entry system and production management and control systems in steel works are integrated is presented as of 1981 in reference [58].

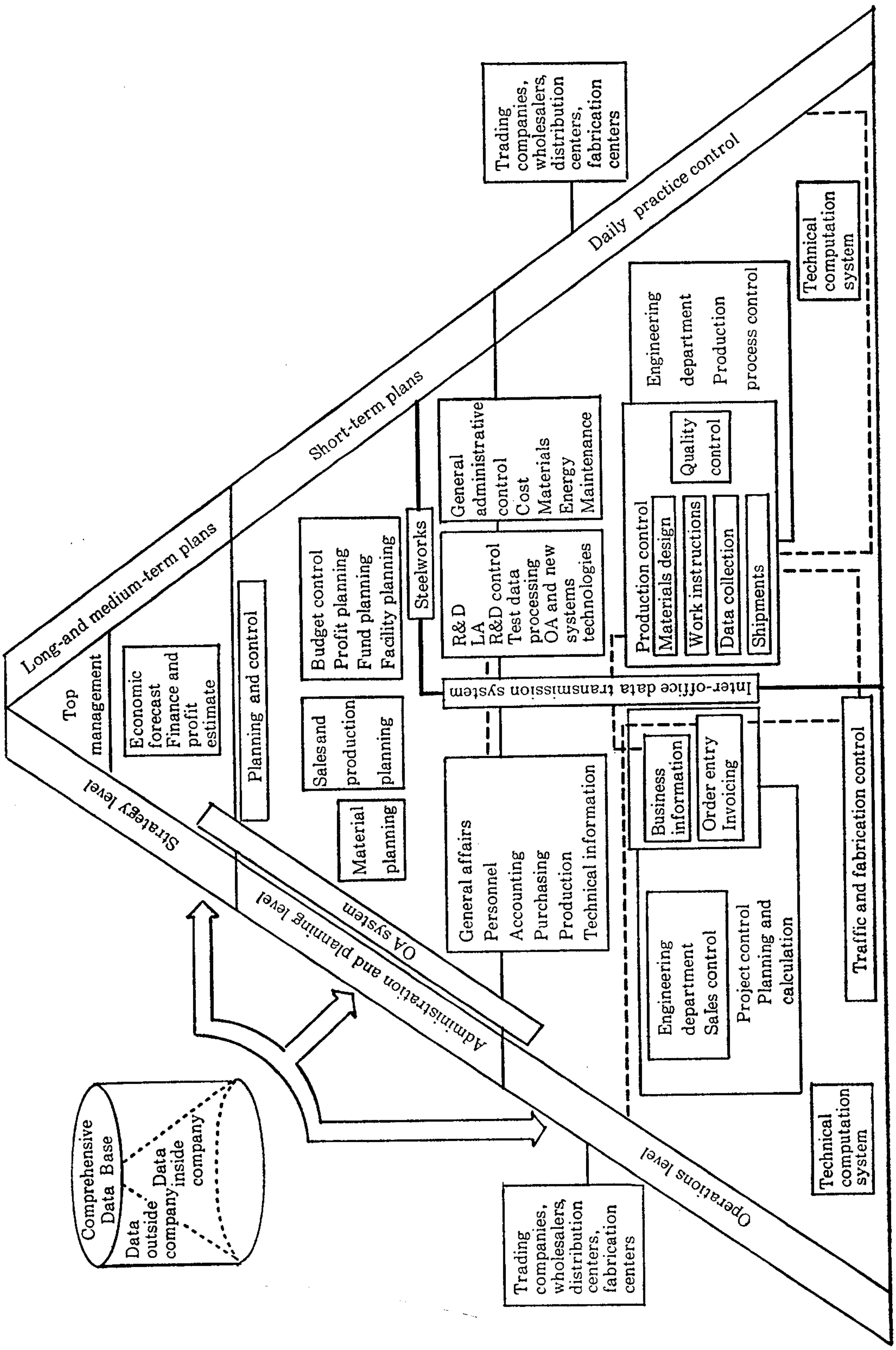
(3) Elaboration of MIS

Parallel with the development of operational level systems, such as order entry and production control, each company was eager to elaborate its MIS by developing various management and decision support systems. By the end of the 1970s, the MIS of each company covered every level and function of management (Fig. 3). Some examples of such development activities follow.

In the case of Yawata, a long range budgeting model was developed in 1966 in relation to a loan from the World Bank. In 1968, a cost matrix model was used for the analysis of investments [11 : p. 583]. In 1973, a human resource information system was developed [11 : p. 348]. And since then various management support systems have been added. As of 1984, 2.7% of total computer hours of the head office were reported to be used for planning purposes [36 : p. 9].

Sumikin, as of 1984, had developed such long and middle range planning support systems as overseas sales planning, production planning and energy planning, even though it reported that there

Fig.3 Typical figure of Management Information Sytsem in the steel industry (as of 1987)



remained much to be developed in other functional planning area. Concerning short range planning support systems, quarterly budgeting support systems consisted of: (a) demand forecast models; (b) predicted order building and sales budgeting models; (c) works budgeting system, including sub-systems of standard values management, production planning, standard cost, standard profit and loss, and budget controls [44].

In the case of Kawatetsu, in 1982, an activity called "integrated reform of management support system" was started. As of 1988, the following systems were revised: (a) raw material purchasing information; (b) machinery purchasing management; (c) budgeting; (d) accounting; (e) personnel; and (e) sub-contracting [45].

(4) Endeavor to Increase System Developing Productivity and Utilization of Software-house

Around the latter half of 1960s, the shortage of system engineers and programmers became noticeable.

Development of production management and control system in the Ogishima works of N.K.K. was carried out, during two and a half years from 1974 to 1976 for the first phase, plus two and a half years from 1977 to 1979 for the second phase of development. Features of this system can be summarized thus: the system consisted of 2 business-use computdrs and 25 process-use computers with two hierarchically structured control levels. As crucial equipment of plant and mills, the process-use computers took care of automatic control, continuously coupled operations among cascaded processes and data gathering. Thus, the operation of heavy plate mills with only 280 workers and of hot strip mills with only 200 workers were achieved, including the process of automated finishing operation of products [46]. As the first trial in the steel industry of automating the operations of the slab yard, coil yard, and product shipping yard was extensively pursued, it succeeded in reducing the number of workers in these areas to 60, compared with an estimated 260 before automation [48 : p.17].

In system development, the foremost concern was how to develop systems with the limited number of system staff and within a limited period before the start-up of the target plants and mills. As one of the various measures to cope with this problem, a policy was adopted to use software houses extensively, which had not been common previously. For the first phase of this development, 2,500 man-months out of a total of 3,7620 man-months and, for the second phase, 1,200 man-months out of a total of 2,050 man-months were relayed to software houses[46].

In the early 1980s, the shortage of system engineers and programmers was widely recognized as a software crisis, and each company was eager to increase its system development productivity as well as to rely more on outside software houses[47 : p.33]. In 1985, the average number of employed system engineers and programmers per company in the steel industry amounted to 147.7, the largest figure of any industry, even exceeding the second largest figure of 118.7 in the information industry. Also the average number of personnel per company sent to steel companies from software houses amounted to 105.5 exceeding the second largest figure of 45.0 in the electrical and machinery industries[48 : p.14].

(5) Promotion of Office Automation (OA) Activity

In the early 1980s, each company actively promoted office automation, aiming to increase productivity in office work. DK (Dynamic Kobe) activity seeking more efficiency in management functions was a typical example[50 : p.37]. In each company, such activities as the positive use of various Office Automation facilities, standardization of paper and format size, installations of optical fiber data highways[51], and making conferences more efficient were promoted [52]. Further, because the use of Chinese chararters had become practical with keyboards, personal computers and word processors spread rapidly in daily office work. The facility purchasing support system of NSC was an example of the automation of office work with the full participation of system users[53]. End user computing encouraged wider use of computers among clerks.

(6) Independence of System Division Subsidiary Companies

Around 1975, several subsidiary software companies were established by steel companies and, towards the end of 1985, the dominant part of the system division of each company was separated as subsidiary companies. The main objectives of the separation were to make the most profit out of the system integration technologies accumulated within the steel industry and to secure enough target applications in other industries to enhance the technologies further.

Kawatetsu started its Kawasaki Steel Systems R&D Corporation in September 1983, Kobe started its Kobelco Systems Corporation in October of the same year, and N.K.K. started its NK-EXA in October 1987. Nippon Steel Information & Communication Systems Inc., NS and I System Service Corp., Nittetsu Hitachi system Engineering Inc., NCI Systems Integration Inc. were all separated from NSC in April of 1988, and Sumitomo Metals' Systems Development Co., LTD. was started in July of 1989. All of these companies are expected to play an important role in the software industry as leading system integrators, taking advantage of the long and abundant experience of large scale sophisticated system development in the steel industry.

6. FUTURE ASPECT OF INFORMATION SYSTEMS IN THE STEEL INDUSTRY

The report on the future aspect of information systems in the industry, written by the information system study team of the Japan Iron & Steel Federation in 1985[48], divided issues into two major categories: (A) system development inside companies: and (B) communication networking among enterprises.

In the field of (A), the following items were cited: (a) ceaseless revision of systems to meet with the increasingly competitive environment; (b) enhancement of strategic and management support systems; (c) support for R&D; (d) full support of information systems for engineering divisions; and (e) promotion of advanced OA and communication networking activities.

In the field of (B), the following items were cited: (a) promotion of structured communication networks among subsidiary and related companies; (b) attainment of higher office work productivity through communication networks among related enterprises; (c) extensive use of international communication networks; and (d) enrichment of the data base of the steel industry.

The report also analyzed the issues and the direction of solutions in promoting information system activities as follows:(a) effective counter-measures against the software crisis;(b) securing better inter-operability; (c)enhancement of the availability and reliability of hardware and software; (d)enhancement of availability and reliability of communication networks; (e)enrichment of the data base of the steel industry; (f)counter-measures to suppress the increasing costs of information systems; and (g)legal and other miscellaneous issues.

The report clearly described the issues facing the industry and the direction leading towards solutions. To obtain better solutions, key requirements are a fair amount of highly qualified personnel and clear objectives to which the personnel can direct their effort.

As described so far, the main reasons why information systems in the Japanese steel industry reached a higher level in the earlier period and have maintained that level compared with the steel industries of other countries, can be summarized as follows: the Japanese steel industry: (a) perceived the management necessities of the time; (b)bravely adopted innovative technologies, (c)trained and secured a good number of highly educated interdisciplinary personnel; and (d)responding to management needs, developed systems in newly constructed steel works. Moreover, the timing of these four elements was quite fortunate, as already described. In comparison, the steel industries in other countries seemingly lacked enough personnel and/or adequate steel works to implement these elements in good timing.

However, the demand for the production of the Japanese steel industry has been saturated since 1973, and large investments, such as the construction of new steel works, cannot be expected.

This means less chance for large scale systems to be designed and installed, except in the restructuring of existing ones. Under the circumstances, it will become more and more difficult to acquire new technology, to recruit qualified personnel, or even to keep experienced engineers, as long as system development is confined to steel applications. In order to positively overcome this probable vicious circle, it is important to be able to find other application fields than steel where the accumulated system integration technology is badly needed. In this regard, separation of system divisions into subsidiary companies was significant.

Postscript

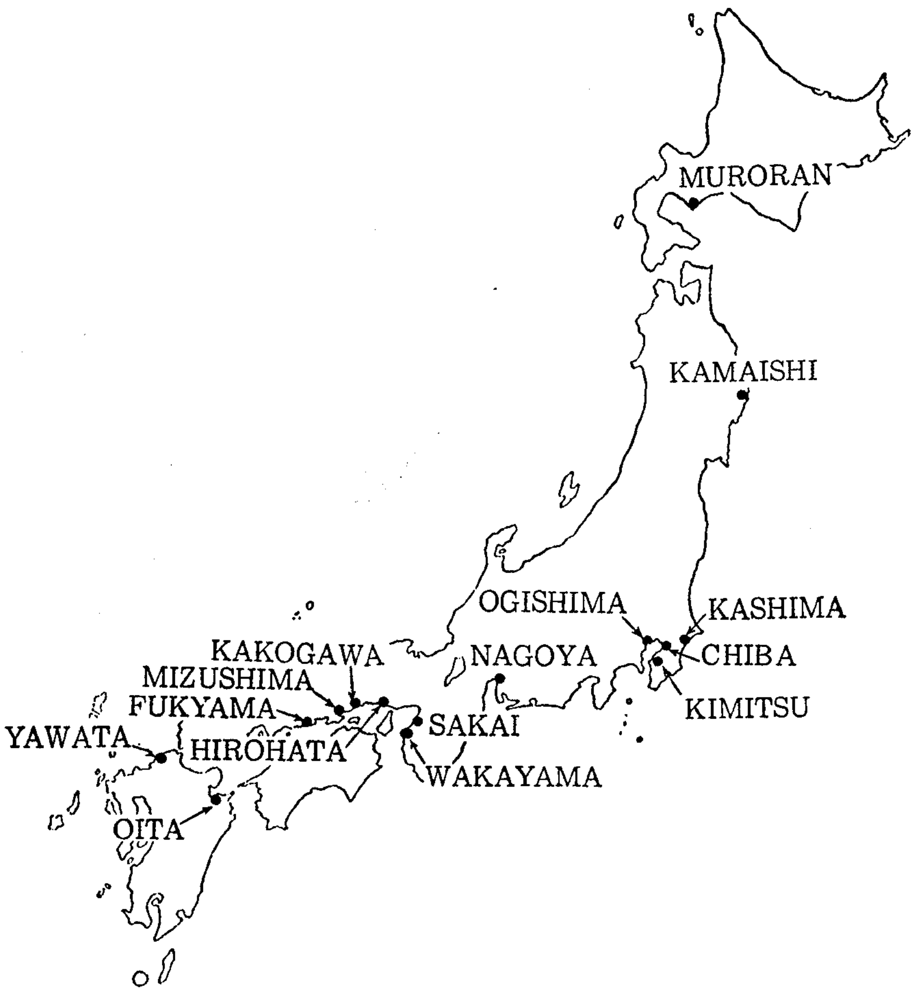
The period of my participation in the systems field in the steel industry was from 1959 to 1987, which covers most of the system developments described in this paper.

In the early stage of computer usage after 1960, we were busy learning from US steel companies how to utilize computers in office work such as accounting and pay roll. However, strong management needs for production increases forced us to study and develop the basic parts of our own production management and control systems. Then another five years had passed while we were busy structuring the world's first on-line production management and control systems.

After 1972, based upon these experiences, we started system cooperation with European steel companies and later with the US, through which I realized that thd Japanese steel industry had had a particularly fortunate environment for developing information systems.

In this paper, I have tried to overview the development of infor-

Fig.4 Location of Major Steel Works in Japan



mation systems in the Japanese steel industry, and to investigate its uniqueness. For this purpose, the analysis throughout is from the viewpoint of management needs, technology, human resources, and green field of new steel works where systems were installed, especially in detail in chapter 4.

The study is restricted to the development of systems in the Japanese steel industry. However, I look forward to making the same kind of studies of the American and European steel industries.

As a reference, Fig. 4 shows the Location of Main Steel Works in Japan as of 1988.

Acknowledgements: I wish to express my deep gratitude to Professor Bela Gold of Claremont Graduate School for his encouragement and advice. Thanks also to Professor Kevin R. Gregg of St. Andrew's University in Osaka for his comments of the style of this paper.

[Abbreviation of Company names]

NSC	Nippon Steel Corp.
Shinnittetsu	Nippon Steel Corp.
N.K.K.	Nippon Kokan K.K.
Sumikin	Sumitomo Metal Industry co.
Kawatetsu	Kawasaki Steel Corp.
Kobe	Kobe Steel co.
Yawata	Yawata Iron and Steel co.
Fuji	Fuji Iron and Steel co.

(Yawata and Fuji merged to form NSC in 1970)

[references]

As for the references written in Japanese, for convenience, an arbitrary English translated title ie shown in parentheces.

[1] Kiers L. *The American Steel Industry: Problems, challenges, Perspectives*, Colorado, Westview Press/Boulder, 1980

[2] Gold B., "*Factors Stimulating Technological Progress in Japanese Industry: the Case of Computerization in Steel*", The quaterly Review of Economics & Business, Bureau of Economics & Business. Bureau of Economics & Business Re search, Volume 18, Winter 1978, Number 4, University of Illinois

[3] Inoue Y. "Nihon Kigyo ni okeru Jouhouka no Shinnten", *Sengo Nihon no Kigyo Keiei*, Tokyo, Bunshindo, 1991 ("Development of Information Systems in Japanese Industry", Management of Postwar Japanese Enterprizes)

[4] Kawasaki T. *Japan's Steel Industry*, Tokyo, Tekko Sinbun Sha, 1988

[5] Nihon Tekko Renmei, *Sengo Tekko Shi*, Tokyo, Nihon Tekko Renmei, 1959 (History of Postwar Japanese Steel Industry)

[6] Nihon Tekko Renmei, *Tekko 10 Nen Shi Showa 33–42*, Tokyo, Nihon Tekko Renmei, 1969 (History of Japanese Stell Industry from 1958 to 1967)

[7] Nihon Tekko Renmei, *Tekko 10 Nen Shi Showa 43–52*, Tokyo Nihon Tekko Renmei, 1981 (History of Japanese Stell Industry from 1968 to 1977)

[8] Nihon Tekko Renmei, *Tekko 10 Nen Shi Showa 53–62*, Tokyo, Nihon Tekko Renmei, 1988 (History of Japanese Stell Industry from 1978 to 1987)

[9] Shin Nihon Seitetsu, *Honoo to tomoni: Yawata Seitetsu Kabushiki Kaisha Sha Shi*, Tokyo, Shin Nihon Seitetsu, 1981, (With Flames: History of Yawata Iron and Steel Co. Ltd.)

[10] Shin Nihon Seitetsu, *Honoo to Tomoni: Fuji Seitetsu Kabushiki Kaisha Sha Shi*, Tokyo, Shin Nihon Seitetsu, 1981, (With Flames: History of Fuji Iron and Steel Co. Ltd.)

[11] Shin Nihon Seitetsu, *Honoo to Tomoni: Shin Nihon Seitetsu Kabushiki Kaisha Sha Shi*, Tokyo, Shin Nihon Seitetsu, 1981, (With Flames: History of Nippon Steel Corp.)

[12] Shin Nihon Seitetsu Yawata Seitetsusho, *Yawata Seitetsusho 80 Nnen Shi –Sogo Shi –*, Yawata, Yawata Seitetsusho, 1980, (History of Yawata Works–General History–)

[13] Shin Nihon Seitetsu Yawata Seitetsusho, *Yawata Seitetsusho 80 Nnen Shi Bvmon Shi Jo*, Yawata, Yawata Seitetsusho, 1980, (History of Yawata Works –Functional History 1–)

[14] Shin Nihon Seitetsu Yawata Seitetsusho, *Yawata Seitetsusho 80 Nnen Shi Bumon Shi Ge*, Yawata, Yawata Seitetsusho, 1 980, (History of Yawata Works –Functional History 2–)

[15] Shin Nihon Seitetsu Kimitsu Works, *Hibi Aratani: Kimitsu Seitetsusho 20 Nenn Shi –Bumon Shi*, Kimitsu, Kimitsu Seitetsusho, 1985, (20 Years' History of Kimitsu Works)

[16] Nihon Kokan Kabushiki Kaisha, *Nihon Kokan Kabushiki Kaisha 70 Nen Shi*, Tokyo, Nihon Kokan Kabushiki Kaisha, 1982, 70 Years History of Nihon Kokan Co. Ltd.)

[17] Kawasaki Seitetsu Kabushiki Kaisha, *Kawasaki Seitetsu 25 Nen Shi*, Osaka, Kawasaki Seitetsu Kabushiki Kaisha 1976, (25 Years History of Kawasaki Seitetsu Co. Ltd.)

[18] Kabushiki Kaisha Kobe Seikosho, *Kobe Seiko 80 Nen Shi*, Kobe, Kabishiki Kaisha Kobe Seikosho, 1986, (80 Years' History of Kobe Seikosho Co. Ltd.)

[19] Sumitomo Kinzoku Kogyo Kabushiki Kaisha, *Sumitomo Kinzoku Kogyo Saikin 10 Nen Shi*, Osaka, Sumitomo Kinzoku Kogyo Kabushiki Kaisha,

1967, (Recent 10 Years History of Sumitom Kinzoku Kogyo Co. Ltd.)

[20] Sumitomo Kinzoku Kogyo Kabushiki Kaisha, *Sumitomo Kinzoku Kogyo Saikin 10 Nen Shi*, Osaka, Sumitomo Kinzoku Kogyo Kabushiki Kaisha, 1977, (Recent 10 Years History of Sumitom Kinzoku Kogyo Co. Ltd.)

[21] Kawasaki T., *Nihon Tekkogyo -Sono Kiseki-*, Tokyo, Tekko Shinbun Sha, 1983, (Japan's Steel Industry)

[22] Nihon I.B.M. Kabushiki Kaisha, *Nihon I.B.M. 50 Nen Shi*, Tokyo, Nihon I.B.M. Kabushiki Kaisha, 1988, (20 Years' History of Nihon I.B.M.)

[23] Nihon I.B.M. Kabushiki Kaisha, *Konpyuta Hattatsu Shi -IBM wo Chushin ni*, Tokyo, Nihon I.B.M. Kabushiki Kaisha, 1988, (History of Computer Development -Mainly I.B.M. Computer—)

[24] Ogoshi H. Inoue Y., "Computer System Used as Production Planning Tool at Yawata Works", *Iron and Steel Engineer*, pp. 128–133., July,1965

[25] Minamizawa N., *Konpyuta Hattatsu Shi*, Tokyo, Nihon Keizai Shinbun Sha, 1986 (History of computer usage)

[26] Yonehana M., *Nihon Keiei Kikaika Shi*, 1975 (History of Management Information Systems in Japan)

[27] Natsume D., *Kimitsu Sogo Joho Shori Sisutemu*, Tokyo, IBM Plant MIS Symposium, 1976, (Kimitsu Integrated Information System)

[28] Inoue Y., et al., "*Practical Management and Control Systems in The Steel Industry*", IFAC Preprints CS–5, Tokyo, 1981

[29] Nishida Y. et. al., "*Tekkougyo ni okeru Konpyuta Riyo no Kokusai Hikaku*", Tekkokai, NO. 12, 1979, Tokyo, Nihon Tekko Renmei, (International Comparison of Computer usage in the Steel industry)

[30] Nihon Joho Kaihatu Kyokai, *Konpyuta Hakusho -1070-*, Tokyo, Nihon Joho Kaihatsu Kyokai, 1971 (White Paper on Computer Usage)

[31] Kagawa T., "Tekko Gyo to MIS", *Tekkokai*, No. 4 1969, Tokyo, Nihon Tekko Renmei, (Steel Industry and MIS)

[32] Nihon Seisansei Honbu, *Amerika no MIS -Hobei MIS Shisetu Dan no Hokokusho-*, Tokyo, Nihon Seisansei Honbu, 1968, (MIS in the US, Report of Top Management MIs Study Mission)

[33] Nihon Tekko Renmei, "Showa 46 Nen no Nihon Tekkogyo Kaiko", *Tekkokai*, NO. 5, 1972, Tokyo, Nihon Tekko Renmei, (Retrospection of 1971 in Japanese Steel Industry)

[34] Inoue Y., "Consideration of Computer Control of A Batch–Type Furnace",

M.S. Thesis, Ohio, Case Institute of Technology, 1960

[35] Nihon Tekko Renmei, "Showa 54 Nen no Nihon Tekkogyo Kaiko", *Tekkokai*, No.5, 1980, Tokyo, Nihon Tekko Renmei, (Retrospection of 1979 in Japanese Steel Industry)

[36] Shin Nihon Seitetsu, "Shoene, shoshigen, Sozai Kakumei Jidai to Tekkogyo no Konpyuta Sisutemu", *Tetsu no Wadai,* No. 47, Tokyo, Shin Nihon Seitetsu, 1984, (Computer Usage in the Steel Industry, in the Era of Energy-saving, Resources-saving, and Materian Inovation)

[37] Sakamoto W. et al., "Seitetsusho Seisankanri Sisutemu", *Kawasaki Seitetsu Giho,* Vol. 20 No. 2 1988, Tokyo, Kawasaki Seitetsu

Sakamoto W. et al., "Production Control Systems at Steel Works", *Kawasaki Steel Technical Report, Special Issue on Information Systems,* No.20, June 1989, Tokyo, Kawasaki Steel Corpolation

[38] Nikkan Kinzoku Tokuho, "Sisutemu Zohn Tekkogyo(2)", pp. 3, April 28, 1985, Tokyo, Nikkan Kinzoku Tokuho (System zone, Steel Industry; an Article in journal)

[39] Fujikawa N. et al., "Honsha Seisan Buturyu Kanri Sisutemu", *Kawasaki Seitetsu Giho,* Vol. 20 No. 2 1988, Tokyo, Kawasaki Seitetsu

Fujikawa N. et al., "On-Line Information System for Meeting Order Processing Services, 'KOSMOS II'", *Kawasaki Steel Technical Report, Special Issue on Information Systems,* No. 20, June 1989, Tokyo, Kawasaki Steel Corpolation

[40] Nikkann Kinzoku Tokuho, "Sisutemu Zohn Tekkogyo(21)", May 15, 1985, Tokyo, Nikkan Kinzoku Tokuho (System Zone, Steel Industry; an Article in journal)

[41] Nikkann Kinzoku Tokuho, "Sisutemu Zohn Tekkogyo(37)", June 12, 1985, Tokyo, Nikkan Kinzoku Tokuho (System Zone, Steel Industry; an Article in journal)

[42] Saito M., Tachibana H., "Sin Nittetsu niokeru Shin Ohda Entori Sisutemu", *IBM 1986 Seizo Sochi Kogyo Symposium,* Tokyo, IBM, 1986 (New Order Entry System of Nippon Steel Corporation)

[43] Ito M., "Hanbai Kanri Ryoiki niokeru Konpyuta no Riyo", *Tekkokai,* September 1984, Tokyo, Nihon Tekko Renmei, (Computer Usage in Sales management Area)

[44] Gochi H., "Zensha tekina Keikaku Kanri Ryoiki niokeru Konpyuta

Riyo", *Tekkokai*, September 1984, Tokyo, Nihon Tekko Renmei, (Computer Usage in Corporate Planning Area)

[45] Hirano K. et al., "Keieikanri Bunya Sisutemu no Sogoka", *Kawatetsu Giho*, Vol. 20, No. 2, 1988, Tokyo Kawasaki Seitetsu (Integration of Management Systems)

[46] Takada K., "Ogishima Seisankanri Sisutemu no Kaihatsu wo Furikaette", *IBM 1979 Seizo Sochi Kogyo Symposium*, Tokyo, IBM, 1979 (On development of production Control Systems at Ogishima Works)

[47] Nihon Johoshori Kaihatu Kyokai, "Johoka Hakusho/1989", Tokyo, Nihon Johoshori Kaihatsu Kyokai, 1989 (White Paper on Information and Data Processing)

[48] Nihon Tekko Renmei Johoka Kenkyukai, "Tekkogyo niokeru Johoka no Genjo to Kadai", Tokyo, Nihon Tekko Renmei, 1985 (Present Status and Future Issues of Steel Industry

[49] Nihon Tekko Kyokai, "Tekkogyo niokeru Konpyuta Riyo no Genjo to Tenbo", *Pre-priot for Dai Ichi, Ni Kai Shiraishi Kinen Koenkai*, Tokyo, Nihon Tekko Kyokai, 1982 (Present Status and Future Prospect of Computer Usage in Steel Industry)

[50] "Fairingu Sisutemu no Kakuritsu", *Tekkokai*, July 1983, Tokyo, Nihon Tekko Renmei (On Filing System)

[51] Kawasaki Seitetsu Group, "Tekkogyo no Jimukanri Katsudo- Kawasaki Seitetsu no Baai", *Tekkokai*, July 1983, Tokyo, Nihon Tekko Renmei (Office Automation Activi ties in the Steel Industry – in the case of kawasaki Steel Corporation)

[52] "Kaigi Koritsuka no Suishin", *Tekkokai*, July 1983, Tokyo, Nihon Tekko Renmei (Promotion of Having Efficient Conference)

[53] "KIND Kizai Kobai Sogo Sisutemu", Tokyo, Shin Nihon Seitetsu 1986 (Use of Computers in Purchasing Procedures)

[54] Nihon Tekko Renmei, "Showa 48 Nen no Nihon Tekkogyo Kaiko" *Tekkokai*, May 1974, Tokyo, Nihon Tekko renmei (Retrospection of 1973 in Japanese Steel Industry)

[55] Nihon Tekko Renmei, "Showa 50 Nen no Nihon Tekkogyo Kaiko", *Tekkokai*,May 1976, Tokyo, Nihon Tekko Renmei, (Retrospection of 1975 in Japanese Steel Industry)

[56] Nihon Tekko Renmei, *Tekko Tokei Yoran* 1988, Tokyo, Nihon Tekko

Renmei, 1989 (Statistics of Steel Industry-1988-)

[57] Nozaka Y., *Tekkogyo no Konpyuta Kontororu*, Tokyo, Sangyo Tosho, 1970, (Computer Control in Steel Industry)

[58] Inoue Y., "Large-Scale Computer Systems in the Steel Industry", *Application Development Systems*, Edited by Kunii T., Tokyo, Springer-Verlag, 1986

[59] The Japan iron & Steel Federation, *The Steel Industry of Japan 1988*, 1989, Tokyo, The Japan Iro & Steel Federation

(YOSHISUKE INOUE, Professor, Department of Business Administration. Received July 3, 1992)